FOSSIL WOOD FROM VICTORIAN BROWN COAL

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Abstract

The wood of five species of gymnosperms and two species of angiosperms from Victorian brown coals is described. The genera concerned are *Agathis, Podocarpoxylon, Phyllocladoxylon, Casuarina* and *Banksia*. Problems associated with the formation of the brown coal are discussed.

Introduction

The brown coal deposits of Victoria, which, according to Thomas and Baragwanath (1949), are mainly of Oligocene age but may extend into the Eocene, contain large amounts of fossil wood in an excellent state of preservation. There has been very little research in connection with this wood, the only previous studies being those of Nobes (1922), which dealt with coniferous wood from Yallourn and also from Moorlands in South Australia. The present paper is concerned with material from the brown coal at Yallourn and Bacchus Marsh, and an account is given of the fossil wood of four new species of conifers and two new species of angiosperms. Details are also given of the wood of another coniferous species which had previously only been recorded from Tertiary deposits at Ballarat.

Description of Species

Before describing the woods found in the brown coal, it is necessary to point out that, particularly in the coniferous wood, abnormalities are present in some of the material examined. This point is important because some of the features shown by this type of material could be regarded as characteristic of the normal wood of the species concerned.

The well-known features of so-called compression wood in conifers (Pillow and Luxford 1937, Münch 1937-8, Jaccard 1938) include relatively indistinct growth rings, abundant intercellular spaces in the spring wood, spring wood tracheids rounded in cross-section, rather thick-walled with spiral checks on the secondary walls, and bordered pits showing extended, slit-like orifices. All these features are shown in the material described here as *Podocarpoxylon australe* and *P. minor*, and there is no doubt that the specimens represent compression wood. The rounded tracheids with spiral checks on the walls and the slit-like orifices of the bordered pits are shown particularly clearly in *P. australe* (Pl. XX, figs. 3, 8, 11, 12), and are almost as pronounced in *P. minor*.

From the above, it can be seen that the descriptions of the shape of the tracheids in cross-section, the thickness of the tracheid walls and the distinctness of the annual rings of both *P. australe* and *P. minor* are not necessarily valid for normal wood. However, the annual rings of both species are absent or so feebly developed that it is most unlikely that they were well defined in the normal wood. Descriptions of the bordered pits are considered to be accurate because it was possible to find occasional normal pits in the compression wood.

Groups of distorted tracheids, in which the lumen is reduced or obliterated, occur in much of the coniferous material examined (see P. XX, fig. 4; Pl. XXII, fig. 17). These distorted tracheids usually form tangential bands (presumably rings in many cases) in which the medullary rays are frequently displaced and distorted (Pl. XX, figs. 2, 5), but they may also form radial bands, and the latter type is the only one noted in *Agathis resinifera*. In *Podocarpoxylon australe*, the tangential bands are sometimes associated with clefts filled with very large, thick-walled parenchyma (Pl. XX, figs. 2, 4), and in *P. minor* there are more or less spherical cavities bounded by distorted tracheids. Tangential bands of distorted tracheids and distorted medullary rays were observed in all the species of *Podocarpoxylon* described below, but were not seen in the other coniferous woods.

These bands of distorted tracheids and the associated phenomena are such obvious abnormalities that they are unlikely to affect the accuracy of descriptions of the fossil woods, but they are so conspicuous that they are worthy of note. In many cases, these abnormalities resemble frost rings (Rhoads 1923, Day and Peace 1934). However, Day and Peace showed that abnormalities which are indistinguishable from certain types of frost ring can be produced experimentally by watering trees insufficiently or by immersing their roots in a tank of water, and Tubeuf (1906) noted that similar rings can be produced by lightning. Frost rings frequently show a very large amount of wood parenchyma, and it is of interest to note that this is not present in either the rings in the fossil wood or in those induced by changes in the water relationships. The collapsed tracheids which may occur when green timber of recent trees is dried (Greenhill 1936, Tiemann 1941, Anon. 1942) are similar to some of the abnormal tissue in the fossils, but these collapsed tracheids are not, of course, associated with enlarged parenchyma cells. It may be noted that collapse of this type is very prevalent in Australian timbers, and that wood from trees grown in swampy areas is particularly likely to show it. It is obvious that, until more material of a similar type is obtained, it is not possible to determine the real cause of the abnormal tissue in the fossils, and in fact the cause of the abnormality may not be the same in each case. As the areas of distorted tracheids are discontinuous, it is unlikely that they are the result of compression by the overlying layers, which would probably affect the whole specimen. Specimens in which all the cells are distorted and most of the structural details obliterated have in fact been found.

In *Agathis resinifera*, the secondary walls of many of the tracheids have disintegrated, so that transverse sections show the primary wall surrounding a uniform granular mass without a lumen (Pl. XXII, figs. 13, 17). All stages between cells with normal walls and those in which the secondary wall has become completely indistinguishable can be seen in the sections. The cause of this disintegration is not known.

Finally, it may be noted that the wood described as *Banksia fossilis* has been subjected to fungal attack prior to its preservation in the brown coal. The medullary rays seem to have been the main tissue infected by the fungus, and the ray cells are often filled with hyphae and collapsed so that the lumen is scarcely visible (Pl. XXIII, figs. 11, 14, 15). In contrast to all the other material examined, this wood was extremely difficult to cut, as the sections broke up into small fragments as soon as they were prepared. For this reason, it has been impossible to obtain a complete description of all parts of the wood or a satisfactory estimate of the size of the medullary rays, etc., or to take a full set of photographs. However, it is considered that the description and illustrations are adequate for the subsequent recognition of the species.

In the descriptions which follow each average measurement cited is the mean of 100 measurements.

GYMNOSPERMAE

Araucariaceae

Agathis resinifera sp. nov.

(Pl. XXII, figs. 12-17; Pl. XXIII, figs. 1-7)

TRANSVERSE SECTION. Annual rings indistinct or absent. Tracheids rounded, average tangential diameter 30.5μ ($15-48\mu$), walls $2-8\mu$ thick, primary and secondary walls distinct. Resin plates present in tracheids adjoining medullary rays; the walls of these parts of the tracheids are thicker than those further from the rays. Resinous wood parenchyma present but sparse. Medullary rays uniseriate, resinous.

RADIAL LONGITUDINAL SECTION. Bordered pits on the radial walls of the tracheids sparse to abundant, usually 1-, 2- or 3-seriate, rarely partially 4-seriate. Pits alternate when multiseriate. Average diameter of pits of the spring wood 11.5μ ($7-13\mu$). Pits circular to hexagonal, pores small, short, oval to circular, oblique; the pores on the opposite sides of an individual pit may be at an angle to one another. Resinous parenchyma conspicuous, tranverse walls thin, smooth, pits small, diameter about 5μ.

Medullary rays parenchymatous, cells frequently irregular in shape. Horizontal and end walls thin (about 1μ), more or less smooth, end walls without indentures. Cross-field pits usually oval to circular with a narrow oblique aperture which nearly reaches the border at either end, but the pore may be short and almost circular or else slit-like and extending to the border at either end. Both axes of the pits range from $5-13\mu$ in length. Usual number of pits per cross-field 3-7, average 5, range 1-12. Pits usually in vertical rows, closely placed but rarely flattened at the zone of contact.

TANGENTIAL LONGITUDINAL SECTION. Bordered pits on the tangential walls of the tracheids occasionally present. Medullary rays uniseriate, 1-12 cells high (average nearly 4), usually 2-6. Cells oval to more or less rectangular, average tangential diameter 16μ ($12-28\mu$), average height 41μ ($25-71\mu$). Resin plates in the parts of the tracheids adjacent to the medullary rays conspicuous, up to 200μ in height and with concave ends.

LOCALITY. Yallourn.

COMMENTS. Nobes (1922) described *Dadoxylon* sp. from the Yallourn brown coal, and it is possible that her material represents the same species as that described above. However, her description is incomplete, and could probably apply to several species of either *Agathis* or *Araucaria*, both of which are known to occur in the Yallourn brown coal (Cookson and Duigan 1951). Furthermore, Nobes's illustration shows simple cross-field pits with vertically orientated pores, and this type of pitting has not been observed in *Agathis resinifera*. Greguss (1955) uses the orientation of the pores in the cross-field pits for the separation of some of the living species of *Agathis* and *Araucaria*, and hence it seems probable that this feature is sufficient to separate Nobes's *Dadoxylon* sp. from *Agathis resinifera*.

Nobes made no mention of resin plates in those parts of the tracheids which are adjacent to the medullary rays. This feature, which is very conspicuous in *Agathis resinifera*, appears to be the same as that described for the wood of various living and fossil species of the family Araucariaceae by Penhallow (1907), Thomson (1914), Stopes (1914) and Edwards (1921). The work of Stopes and Edwards refers to fossil species from the Australasian region, and hence these merit further attention. Stopes described *Araucarioxylon novae zeelandii* from a Cretaceous

deposit in New Zealand and, although this wood is rather similar to that of *Agathis resinifera*, there are a number of differences which, together with the difference in the age and geographical location of the two woods, are sufficient to separate them. Edwards gave a fuller account of the wood from the Tertiary of Kerguelen Island which was originally described by Seward (1919) as *Dadoxylon kerguelense*. The wood of *D. kerguelense* is very similar to that of *Agathis resinifera* but, in view of the great distance between the localities at which they were found, it seems advisable to regard them as separate species, at least until more is known of the significance of the small differences in structure which do exist between them.

The difficulties of separating the wood of *Agathis* from that of *Araucaria* are well known (Patton 1928a, Phillips 1941, Greguss 1955). However, in the present case, it was possible to identify the fossil as *Agathis* because of the nature of the bark. This identification is supported by the fact that many characters known to be more common in *Agathis* than in *Araucaria* are present in the fossil. In the earlier paper (Patton 1928a), it was pointed out by the present author that resin in the tracheids and medullary rays is more common in *Agathis* than in *Araucaria*, and resin is abundant in these regions of the fossil. Phillips (1941) believes that 4-seriate rows of bordered pits on the tracheid walls occur in *Agathis* and not in *Araucaria*, and again the fossil shows this character. Greguss (1955) states that wood parenchyma was found only in *Agathis*; there is wood parenchyma in the fossil, but the value of this distinction is uncertain, as Greguss suggests later that there may be very sparse wood parenchyma in *Araucaria*.

It is possible that the fossil wood described above may come from the same species as the one which provided the leaves and cones described by Cookson and Duigan (1951) as *Agathis yallournensis* but, in the absence of any direct evidence of a connection between them, *A. resinifera* must be regarded at present as a separate species. This conclusion is supported by the fact that Cookson and Duigan found a second species of *Agathis* in the brown coal at Bacchus Marsh, and this species may have extended to Yallourn.

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PODOCARPACEAE

Podocarpoxylon australe (F.v.M.) Kräusel

(Pl. XX, figs. 1-12)

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TRANSVERSE SECTION. Annual rings indistinct or absent. Tracheids irregular in outline, circular to polygonal in shape, average tangential diameter 32μ (10-50μ). Tracheid walls thick (4-8μ), primary and secondary walls distinct. Wood parenchyma diffuse, resinous and rather sparse. Medullary rays uniseriate, resinous.

RADIAL LONGITUDINAL SECTION. Bordered pits on the radial walls of the tracheids rather sparse, uniseriate, average diameter in the spring wood 14μ (12-18μ). Pits more or less circular, apertures small, short, oval, oblique; the pores on the opposite sides of an individual pit may be at an angle to one another. Resinous wood parenchyma conspicuous, tranverse walls more or less smooth to nodular, pits small (longest diameter about 6μ), oval, apertures oblique.

Medullary rays parenchymatous. Horizontal and end walls thin ($c.$ 1-$1 \cdot 5\mu$) and more or less smooth, end walls without indentures. Cross-field pits oval, longer diameter 5-12μ (average 8μ), shorter diameter (which coincides with the long axis of the pore) 4-9μ, average $5 \cdot 5\mu$. Pores of the cross-field pits rather narrow, oblique, usually reaching the border at either end. Number of pits per cross-field usually 1, occasionally 2 or 3; when two pits are present, their position varies from vertical to horizontal.

TANGENTIAL LONGITUDINAL SECTION. Occasional small pits, 10-12μ in diameter, on the tangential walls of the tracheids. Medullary rays usually uniseriate, very occasionally (about 2 per cent of the rays) biseriate in a portion which is only one cell high. Rays 1-12 cells high (average 4), usually 2-6. Cells more or less square, average tangential diameter 18μ (10-30μ), average height 23·5μ (12-33μ). Medullary rays which are one or two cells high and the outer rows of rays which are more than two cells high have cells which average 25μ in height, and are thus somewhat higher than the cells of the inner rows of the latter type of ray, which average 20μ.

LOCALITY. Yallourn.

COMMENTS. This wood seems to match the fossil wood from Ballarat Tertiary deposits which was described by Kubart (1923) as *Podocarpoxylon smythii*. Kubart considered that the wood which he investigated was the same as that originally described by von Mueller (1883) as *Spondylostrobus smythii*, but that many of the details shown by von Mueller were inaccurate. Kräusel (1949) changed the name given by Kubart to *Podocarpoxylon australe* because he considered that the specific name *smythii* belongs only to fruits which in fact have no connection with the wood.

There are a few differences between the fossil wood from Yallourn and that investigated by Kubart, but they do not seem to be of sufficient importance to warrant the separation of the woods into two species. Kräusel included the wood described as *Mesembrioxylon* sp., Yallourn A. by Nobes (1922) with *P. australe*, but it is doubtful if this is correct. Judging from the text and the illustrations given by Nobes, her material differs from the wood described above and that investigated by Kubart in that it has no wood parenchyma, the pits on the radial walls of the tracheids have relatively very large, circular apertures and are often biseriate and the cross-field pits are circular and about 7-11μ in diameter. These differences appear to be sufficient to separate Nobes's material from *P. australe*.

Podocarpoxylon minor sp. nov.
(Pl. XXI, figs. 1-8)

TRANSVERSE SECTION. Annual rings indistinct. Tracheids rounded, average tangential diameter 21μ (8-33μ), walls 2-5μ thick, primary and secondary walls distinct. Wood parenchyma diffuse, sparse, with occasional globules of resin. Medullary rays uniseriate, without resin.

RADIAL LONGITUDINAL SECTION. Bordered pits on the radial walls of the tracheids moderately abundant, uniseriate, average diameter in the spring wood 10μ (8-13μ). Pits broadly oval, apertures relatively quite large, oval, oblique; the pores on the opposite sides of an individual pit may be at an angle to one another. Transverse walls of the wood parenchyma very thin, more or less smooth, pits of the parenchyma small (longer diameter about 6μ), oval, apertures oblique.

Medullary rays parenchymatous. Horizontal and end walls thin (about 1μ) and more or less smooth, end walls without indentures. Cross-field pits oval, longer diameter 2·5-7·5μ, average 5μ, shorter diameter (which coincides with the long axis of the pore) 2·5-5·5μ, average 4μ. Apertures of the cross-field pits very narrow, oblique, reaching or exceeding the border at either end. Number of pits per cross-field usually 1, rarely 2 or 3; if 2 pits are present, they are more or less vertically placed.

TANGENTIAL LONGITUDINAL SECTION. Occasional pits, 8-13μ in diameter, on the tangential walls of the tracheids. Medullary rays uniseriate, usually 1-3 cells high, average 2, maximum 7. Cells of the medullary rays more or less oval, average tan-

gential diameter 10μ (5-13μ), average height 15μ (8-20μ). Cells of the inner rows of rays which are more than 2 cells high average a slightly lower height than any other ray cells.

LOCALITY. Bacchus Marsh.

COMMENTS. This wood does not seem to match any of the wood previously described from Australian brown coal deposits or that of any other fossil species with which it might reasonably be compared. Hence it is regarded as a new species, but it must be pointed out that it is structurally very similar to *Podocarpoxylon australe*. The main difference between the two species is one of size; in *P. australe* the tangential diameter of the tracheids, the diameter of the pits on the radial walls of the tracheids, the height and tangential diameter of the medullary ray cells and the longer and shorter diameter of the cross-field pits are all appreciably greater than the comparable dimensions of *P. minor*. There is a certain overlap in all these measurements, but the differences between them are all statistically significant. There are other differences between these two woods, but alone these would probably not suffice to separate them; thus in *P. australe* the pores of the tracheid pits are relatively small, resin is abundant in the wood parenchyma and medullary rays and the rays are 1-12 (average 4) cells high, whereas in *P. minor* the pores of the tracheid pits are relatively large, resin is sparse in the wood parenchyma and absent from the medullary rays and the rays are 1-7 (average 2) cells high.

Podocarpoxylon yallournensis sp. nov.
(Pl. XXI, figs. 9-15)

TRANSVERSE SECTION. Annual rings indistinct, occasionally a narrow band of thick-walled cells present. Tracheids very much rounded, average tangential diameter 22μ (10-30μ), walls thin (1-3μ), limits of individual cells and of primary and secondary walls indistinguishable. Wood parenchyma diffuse, moderately abundant, resinous. Medullary rays uniseriate, resinous.

RADIAL LONGITUDINAL SECTION. Bordered pits on the radial walls of the tracheids abundant, usually uniseriate, occasionally partially biseriate, opposite or alternate. Average diameter of the pits of the spring wood 15μ (12-18μ). Pits more or less circular, surface marked by faint radial striations, apertures large and circular. Resinous wood parenchyma very conspicuous, transverse walls very thin, smooth, pits small (diameter about 5μ) and apertures broad.

Medullary rays parenchymatous. Horizontal and end walls thin (about 1μ or less) and more or less smooth, end walls without indentures. Cross-field pits very variable in size and shape, the longer diameter ranging from 3-10μ. Cross-field pit apertures broad or narrow, reaching the border at points which may constitute the ends of either the long or the short axis of the pit. Borders of the pits frequently indistinguishable. Number of pits per cross-field 1-5, usually only 1-3.

TANGENTIAL LONGITUDINAL SECTION. Occasional small pits, about 10μ in diameter, on the tangential walls of the tracheids. Medullary rays uniseriate, usually 1-2 cells high, average 2, maximum 6. Cells of the rays more or less elliptical, average tangential diameter 21μ (10-35μ), average height 28μ (15-40μ).

LOCALITY. Yallourn.

COMMENTS. This wood does not seem to be the same as any of that previously described from Australian brown coal deposits, although it bears some resemblance to the wood from Yallourn named *Cupressinoxylon* sp. by Nobes (1922). However, there are only 1-2 pits in each cross-field in Nobes's material, the apertures of these

pits apparently do not usually reach the border and the medullary rays are usually 1-20, occasionally 1-30 cells high. The work of Bannan (most of which is listed in Bannan 1954) shows that, at least in many North American conifers, the height of the medullary rays is a character which can vary considerably in a single individual, but Greguss (1955) uses the height of the rays in separating the wood of present-day species of *Podocarpus*, *Dacrydium* and *Phyllocladus*, and it seems probable that the very great difference between the height of the rays in Nobes's wood and the one at present under consideration, together with the differences in the cross-field pitting, are sufficient to separate them. Kräusel (1949) considers that *Podocarpoxylon totara* Evans (Evans 1937) includes both *Cupressinoxylon* sp. Nobes and *Mesembrioxylon* sp., Moorlands A., Nobes, but *P. yallournensis* has even less in common with *P. totara* and this species of *Mesembrioxylon* than it has with *Cupressinoxylon* sp., and in fact it is doubtful whether these three species which were united by Kräusel belong together.

Of the other fossil species with which it may be compared, *P. yallournensis* appears to be closest to *Cupressinoxylon antarcticum* Beust from the Tertiary of Kerguelen Island. This wood was fully described by Edwards (1921), who considered that it might in fact belong to *Podocarpoxylon*. From Edwards's description and illustrations, it appears that the cross-field pitting is the same in *P. yallournensis* as in *C. antarcticum*. However, Edwards believed that the appearance of the cross-field pits was probably altered by decay, and in view of this uncertainty and of some differences between the other parts of the two woods, it seems unwise at present to regard them as one species. It is, of course, of interest that this similarity to a Kerguelen form is also shown by *Agathis resinifera*.

Phyllocladoxylon annulatus sp. nov.
(Pl. XXII, figs. 1-11)

TRANSVERSE SECTION. Annual rings conspicuous, 7-23 cells wide. Tracheids rectangular to subrectangular, average tangential diameter 28μ (10-43μ), walls 4-11μ in thickness, thin in the spring wood and very thick in the autumn wood. Primary and secondary walls distinct. Wood parenchyma absent. Medullary rays uniseriate, doubtfully resinous.

RADIAL LONGITUDINAL SECTION. Bordered pits on the radial walls of the tracheids abundant, usually uniseriate, occasionally biseriate and opposite or alternate. Bars of Sanio present. Average diameter of the pits in the spring wood 15μ (12-18μ). Pits more or less circular, apertures oblique, rather small, circular to broadly oval with an elongated ridge on each side. The pores on the opposite sides of an individual pit are usually at an angle to one another. Vestured pits (as described by Greguss 1955) occasionally present. Resin rings present, usually very thin.

Medullary rays parenchymatous, cells frequently irregular in outline and similar to those of *Microcachrys* (Patton 1928a). Horizontal and end walls thin (about 1μ) and more or less smooth, end walls without indentures. Cross-field pits oval, large, longer diameter 10-20μ, shorter diameter (which coincides with the long axis of the aperture) 8-13μ. Apertures of the cross-field pits oblique, usually oval and nearly reaching or reaching the border at either end, occasionally slit-like and reaching or exceeding the border. Number of pits per cross-field usually 1, rarely 2 and vertically or horizontally placed.

TANGENTIAL LONGITUDINAL SECTION. Pits on the tangential walls of the tracheids quite abundant, 10-13μ in diameter. Medullary rays uniseriate, usually 1-3 cells high, average 2, maximum 7. Cells of the medullary rays more or less elliptical,

average tangential diameter 9μ (5-15μ), average height 19μ (8-28μ). Cells of the inner rows of rays which are more than 2 cells high average 15μ in height compared with 20μ for the other ray cells. Resin rings usually very thin.

LOCALITY. Yallourn.

COMMENTS. Wood which Kräusel (1949) regards as *Phyllocladoxylon*, but which was originally named *Mesembrioxylon* sp.. Yallourn B. by Nobes (1922), has already been described from the Yallourn brown coal, but there is no doubt that it is different from the wood described above. The latter does not agree with any of the other wood from the brown coal which has previously been described, nor with any other fossils, such as the one from Stony Creek (Patton 1928b), with which it might reasonably be compared, and hence it is regarded as a new species.

Cookson and Pike (1954a) described leaves of *Phyllocladus morwellensis* Deane and pollen grains of *P. palaeogenicus* Cookson and Pike from the Yallourn brown coal, and it is possible that these may have come from the same species as *Phyllocladoxylon annulatus*. However, there is no evidence of a connection between the three forms, and, of course, the fossil wood does not necessarily represent a species of *Phyllocladus*. Cookson and Pike suggest that the leaves are unlikely to represent *Phyllocladus aspleniifolius* (Labill.) Hook. f. (syn. *P. rhomboidalis* Rich.), the only existing Australian species of *Phyllocladus*. It is therefore of interest to note that the wood of *Phyllocladoxylon annulatus* is also different from the wood of this species. The wood of *P. annulatus* is rather similar to that of *Phyllocladus trichomanoides* D. Don., one of the two species of *Phyllocladus* which occur in New Zealand at the present day. The cross-field pits of the two woods are alike, and the ridges on the edge of the aperture in the tracheid pits of the fossil match those of the recent species. However, neither of these characters is restricted to *Phyllocladus*, and it cannot be said that all structures in the fossil are exactly the same as those of *P. trichomanoides*.

ANGIOSPERMAE

CASUARINACEAE

Casuarina latrobei sp. nov.

(Pl. XXIV, figs. 1-10)

TRANSVERSE SECTION. Annual rings indistinct or absent. Vessels large, circular to elliptical, sparse, scattered, often filled with tyloses. Vasicentric tracheids present. Fibres thick-walled, lumen almost obliterated. The fibres are arranged in more or less rectangular areas bounded radially by the medullary rays and tangentially by bands of parenchyma 1-3 cells wide. Medullary rays of two kinds, uniseriate and multiseriate, the latter heterogeneous and consisting of parenchyma with an interlacing network of conspicuously pitted fibres.

RADIAL LONGITUDINAL SECTION. Tangential bands of parenchyma conspicuous, fibres without obvious pitting. Vasicentric tracheids strongly pitted. Heterogeneous medullary rays very high, parenchyma cells irregular in size, network of pitted fibres conspicuous.

TANGENTIAL LONGITUDINAL SECTION. Uniseriate medullary rays abundant. Network of pitted fibres in the multiseriate rays very conspicuous.

LOCALITY. Yallourn.

COMMENTS. As far as is known, there are no previous accounts of the detailed structure of *Casuarina* wood from any Australian Tertiary deposits. However, the occurrence of *Casuarina* wood at Yallourn was noted by Chapman (1925), a *Casu-*

arina cone from the Yallourn brown coal was recorded by Pike (1952) and Cookson and Pike (1954b) described pollen grains of *Casuarinidites cainozoicus* from the same locality. It is probable that some of these forms belong to the same species, but there is no evidence regarding this point at present. The specific name for the wood described in the present paper refers to the extensive brown coal deposits (including the ones worked at Yallourn) of the Latrobe valley.

PROTEACEAE

Banksia fossilis sp. nov.

(Pl. XXIII, figs. 8-15)

TRANSVERSE SECTION. Vessels rather thin-walled, variable in size and shape, arranged in groups which are associated with wood parenchyma to form curved tangential festoons between the large medullary rays. Wood parenchyma in bands, apparently 1-3 cells wide, on the concave side of these festoons. Occasional tracheids apparently also present in the festoons. Medullary rays of two distinct types, small uniseriate rays and large multiseriate ones which are usually about 5-9 cells wide but may be up to at least 14 cells wide. Vessels, parenchyma and medullary rays often filled with a reddish-brown substance, presumably resin. Fibres very thick-walled, lumen almost obliterated, pits simple. Fibres arranged in curved tangential bands between the festoons of vessels and wood parenchyma.

RADIAL LONGITUDINAL SECTION. Pits of vessel segments small. Cells of uniseriate medullary rays apparently all erect.

TANGENTIAL LONGITUDINAL SECTION. Uniseriate medullary rays usually 1-5 cells high, maximum 12. Multiseriate rays up to at least 2·5 mm. high and at least 0·3 mm. wide.

LOCALITY. Bacchus Marsh.

COMMENTS. This fossil clearly has the type of wood structure which Chattaway (1948a) shows to be characteristic of many recent members of the family Proteaceae. The wood structure of the fossil cannot be used to identify it as a particular genus as, from the information given by Chattaway, it could belong to *Banksia*, *Dryandra* or *Hakea*. However, the nature of the bark on the fossil definitely places it in *Banksia*, and this identification is supported by the fact that the wood structure seems to have slightly more in common with that of *Banksia* than *Hakea*, while the present-day distribution of *Dryandra* (which occurs only in Western Australia) renders it somewhat unlikely that the fossil belongs to this genus. Chattaway (1948b) gives details of the vascular tissue which may occur in the medullary rays of *Banksia* and *Dryandra*; this feature is not known in any other members of the Proteaceae, and hence could be used to identify a fossil as either *Banksia* or *Dryandra*. Unfortunately, no vascular tissue was observed in the rays of the fossil described above. This may have been due to the frequent distortion of the rays and the generally unsatisfactory nature of the sections, but Chattaway points out that the frequency of vascular tissue in the rays is variable, and its absence, even in perfect sections, would not disprove the identification of the fossil as *Banksia*.

Chattaway (1948a) shows that, in many genera with the *Banksia* type of structure, there is a great variation in vessel size, the smaller ones being little bigger than the parenchyma cells with which they are associated. The walls of the vessels of the fossil are rather thin, and, in the absence of satisfactory longitudinal sections, small vessels cannot be distinguished from parenchyma cells. Consequently, although it appears probable that the bands of parenchyma on the concave side of the festoons

are 1-3 cells wide, it is not possible to be certain on this point, or to determine whether the vessels grade into tracheids.

There are no known records of the detailed structure of proteaceous woods from Australian Tertiary deposits with which the wood described above can be compared, and therefore it must be regarded as a new species. However, there is an abundance of other evidence to show that *Banksia*, or at least forms closely related to it, existed at the time when the brown coal was formed. Thus Deane (1925) recorded *Banksia* leaves from Yallourn, Cookson and Duigan (1950) described *Banksia* cones and the leaves of six species of *Banksieaephyllum* from the Yallourn open cut and Cookson (1950) described pollen grains, which she named *Banksieaeidites*, from the same locality.

Discussion

From the material examined, it appears that the forests which formed the brown coal were almost purely coniferous, and hardwoods, although occasionally present, may be regarded as accidental. The deposits consist largely of tree-trunks which fell where they grew; some fell while still on the stump, and the roots are therefore upright, while others rotted at water level, leaving the stumps still in their original position.

Owing to the general absence of mineral matter in the coal, the conclusion must be drawn that the trees grew in a swamp which was sinking slowly, so slowly that, during the lifetime of the trees, water did not encroach seriously upon the trunks and the trees could therefore reach an age and size equivalent to those on dry land. In the case of trees which fell from the stump, it may be concluded that there were periods of equilibrium in the sinking and that the trees decayed at the water-air level.

The swamp in which the forests occurred must have provided a very soft, organic medium for the growth of the vegetation, and it is surprising that this permitted large trees to obtain an adequate root-hold. This does not appear to have been due to the roots having reached a very great depth, and there is no evidence of any provision for a supply of air to the roots as in the Mangrove (*Avicennia officinalis*) or the Bald Cypress (*Taxodium distichum*).

One of the most interesting woods present in the brown coal is that of the Kauri Pine, *Agathis*, for this genus extends today only from Malaya in the north to the northern part of New Zealand. In Australia, Kauri does not come further south than Queensland, but in New Zealand it extends southwards to a latitude similar to that of Melbourne. However, the temperatures in the New Zealand areas are higher than those of Melbourne, although not as high as those of Sydney.

According to Cranwell and Moore (1936), who describe the vegetation with which Kauri occurs, the plant association is definitely rain-forest. They also state that Kauri formerly grew in the South Island. The present occurrence in the extreme north of New Zealand may therefore be regarded as the last remnant of its retreat northwards.

The temperatures at Gabo Island (which is just off the extreme east of Victoria) are very similar to those of Auckland, N.Z., where Kauri grows at the present day, but, although rain-forests extend down the east coast of Australia and just pass Gabo Island, Kauri is left far to the north. However, the rain-forest is probably not a relic, as is the Kauri in New Zealand, but a readvance southward due to a climatic amelioration since Pleistocene times.

Although far from the tropics, Kauri is maintained in New Zealand because of the mild winter temperatures and the even distribution of the rainfall throughout the year. All other areas in which *Agathis* grows are tropical, and its presence in

Victoria during Oligocene times indicates a climate which was warmer than that of the present day.

It seems probable that at least some of the woods recorded here as *Podocarpoxylon* do in fact represent species of *Podocarpus,* and in any case there is other independent evidence of the presence of *Podocarpus* in the brown coal at both Yallourn and Bacchus Marsh (Cookson and Pike 1953). However, this does not imply any particular climatic conditions, as *Podocarpus* has a wide distribution at the present time, ranging from Australia northwards to Japan, westwards to South Africa and eastwards to South America and the West Indies. Within Australia, it occurs over a wide range of climatic conditions from the Australian Alps, where the snow lies deep for several months of the year (*P. alpina* R.Br.), to the tropical lowlands (*P. elata* R.Br.). Florin (1940) considers that *Podocarpus* originated in the Southern Hemisphere and that its distribution in Tertiary times was as far south as Antarctica. If this is true, the presence of the genus in the brown coal is not surprising, particularly in view of the fact that *Podocarpus* has persisted to the present day and still has a very wide distribution.

In spite of the fact that the situation may be confused in some cases by the presence of compression wood (see p. 129) it is of interest to note that, in the coniferous woods identified here from the brown coal, there are four species in which the annual rings are ill-defined or absent and one in which they are sharply defined. The lack of obvious rings of growth is, at the present day, a feature of the wood of tropical species—e.g. *Agathis* and *Araucaria* in the high rainfall areas (Patton 1928a)—but it is not restricted to such species. Thus, in Victoria today, none of the trees such as the Murray Pine (*Callitris*) or *Eucalyptus* shows sharply defined rings of growth comparable with those of trees from the northern temperate lands. This is true for Victorian trees from areas with a high or a low rainfall, and is due to the fact that the winter temperatures are not sufficiently low to cause a cessation of activity. Thus the absence or lack of definition of annual rings in the wood of the four fossil species does not necessarily indicate climatic conditions which differ from those of the present day.

The presence of fossil wood with sharply defined annual rings complicates the matter. The very distinct rings of *Phyllocladoxylon* are similar to those found in the wood of *Athrotaxis, Phyllocladus* and *Dacrydium* in Tasmania at the present day (Patton 1928a), and are as well defined as those of the Northern Hemisphere conifers. In the colder parts of the Northern Hemisphere, the well-defined rings of growth in both angiospermous and gymnospermous trees are accompanied by annual defoliation in the former, and are associated with winter temperatures which are too low for growth. However, even in Tasmania the angiospermous trees lack well-developed annual rings and, with the exception of the shrub *Nothofagus gunnii* (Hook.) Oerst., none of the woody angiosperms is deciduous.

Phyllocladoxylon persisted in Australia from the Oligocene to the Pleistocene, but is now extinct, and the reason for the extinction of trees with well-defined annual rings on the mainland while they still exist in Tasmania is not clear. Tasmania is colder than Victoria, and therefore the low temperatures of the glacial periods cannot have been the cause. Nor can it have been dryness for, although there have been changes in the vegetation during the Tertiary and Quaternary periods, there is a core of vegetation with tropical affinities which has persisted to the present day (Patton 1933). It can only be assumed that this character of well-defined rings is a feature of the species and is independent of environment. Hence the wood of *Phyllocladoxylon* at Yallourn is not inconsistent with the presence of other species in which growth rings are ill-defined or absent.

D

The only angiosperm woods found in the brown coal were those of *Casuarina* and *Banksia*. Wood belonging to these genera has only been found in the uppermost layers of the brown coal, where it was usually only spasmodically present; it is probable that this occurrence is quite accidental and that the logs were derived from the high ground surrounding the swamp. However, there was an almost pure layer of *Banksia* wood at one locality at Bacchus Marsh; this was several feet in thickness, and it suggests that, although a depression existed, conditions suitable for coniferous species no longer prevailed.

Casuarina and *Banksia* are typically Australian genera, both of which are now widespread from eastern to western Australia. The former, however, extends into northern Australia, and has one species which passes across to the coasts of tropical islands and forms part of the coastal forest (Schimper 1903). The genus *Banksia* is found in areas with a low to moderate rainfall; in Victoria today there are five species, one on the coastal dunes, one on the heath, one in the Mallee, one in east Gippsland forests and one in the forests near Melbourne. *Casuarina* is not as large a genus as *Banksia*, but its species extend over a wider range of environmental conditions. Thus *Casuarina decaisneana* (F.v.M.) occurs in central Australia where the rainfall is less than five inches per year, while *C. cunninghamiana* Miq. grows on river-banks in coastal New South Wales where the annual rainfall is over ninety inches. However, the genera *Banksia* and *Casuarina* may both be regarded, in general, as xerophytic. Xerophytism is not, of course, controlled only by rainfall, but is also dependent on the quality of the soil. The presence of *Banksia* and *Casuarina* around the swamp areas forming the brown coal suggests that the soil on the hills was thin, and that hence the vegetation there did not reflect the highly favourable climatic conditions.

Acknowledgements

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Explanation of Plates

Photographs by Dr. Suzanne L. Duigan

PLATE XX

Podocarpoxylon australe (F.v.M.) Kräusel

Fig. 1.—Transverse section. × 100.
Fig. 2.—Transverse section showing distorted tracheids, distorted medullary rays and abnormally
    large parenchyma cells. × 100.
Fig. 3.—Transverse section. × 100.
Fig. 4.—Transverse section of distorted tracheids and some of the abnormally large parenchyma
    cells shown in Fig. 2. × 330.
Fig. 5.—Transverse section showing distorted tracheids and distorted medullary rays. × 100.

Fig. 6.—Radial longitudinal section showing the high outer cells and the low inner cells of a
  medullary ray which is four cells high. × 600.
Fig. 7.—Radial longitudinal section showing the pits of a single cross-field. × 1,000.
Fig. 8.—Radial longitudinal section of a medullary ray showing the arrangement of the cross-
  field pits and the slit-like extensions to their pores. × 600.
Fig. 9.—Tangential longitudinal section. × 100.
Fig. 10.—Radial longitudinal section, showing pits on the radial wall of a tracheid. × 600.
Fig. 11.—Radial longitudinal section, showing slit-like extensions to the apertures of the pits on
  the radial walls of the tracheids. × 600.
Fig. 12.—Tangential longitudinal section, showing a medullary ray and spiral checks on the walls
  of the tracheids. × 330.

PLATE XXI

Podocarpoxylon minor sp. nov.

Fig. 1.—Transverse section. × 100.
Fig. 2.—Transverse section. × 330.
Fig. 3.—Tangential longitudinal section. × 100.
Figs. 4, 5.—Radial longitudinal section, showing the pits on the radial walls of the tracheids.
  × 600.
Fig. 6.—Radial longitudinal section of a medullary ray, showing the arrangement of the cross-
  field pits. × 600.
Fig. 7.—Radial longitudinal section of a medullary ray, showing a cross-field pit. × 1,000.
Fig. 8.—Tangential longitudinal section of a medullary ray. × 330.

Podocarpoxylon yallournensis sp. nov.

Fig. 9.—Transverse section. × 100.
Fig. 10.—Radial longitudinal section. × 100.
Fig. 11.—Tangential longitudinal section. × 100.
Fig. 12.—Transverse section. × 330.
Fig. 13.—Radial longitudinal section, showing the pits on the radial walls of the tracheids.
  × 600.
Fig. 14.—Radial longitudinal section of a medullary ray, showing the pits in two cross-fields.
  × 1,000.
Fig. 15.—Tangential longitudinal section of two medullary rays. × 330.

PLATE XXII

Phyllocladoxylon annulatus sp. nov.

Fig. 1.—Transverse section, showing the junction of spring and autumn wood. × 100.
Fig. 2.—The same. × 330.
Fig. 3.—Radial longitudinal section. × 100.
Fig. 4.—Radial longitudinal section, showing the pits and Bars of Sanio on the radial walls
  of the tracheids. × 600.
Fig. 5.—Radial longitudinal section of a medullary ray, showing the arrangement of the cross-
  field pits. × 600.
Fig. 6.—Radial longitudinal section, showing a single cross-field. × 1,000.
Fig. 7.—Radial longitudinal section, showing vestured pits on the radial wall of a tracheid.
  × 1,000.
Figs. 8, 9.—Tangential longitudinal section of tracheids, showing resin rings. × 600.
Fig. 10.—Tangential longitudinal section. × 100.
Fig. 11.—Tangential longitudinal section of a medullary ray. × 330.

Agathis resinifera sp. nov.

Fig. 12.—Radial longitudinal section. × 100.
Fig. 13.—Transverse section, showing the arrangement of the resin plates. A few abnormal
  cells, in which the secondary wall has disintegrated, are present. × 100.
Fig. 14.—Transverse section, showing the junction of spring and autumn wood. × 100.
Fig. 15.—Tangential longitudinal section. × 100.
Fig. 16.—Tangential longitudinal section, showing a medullary ray and a resin plate. × 330.
Fig. 17.—Transverse section, showing a distorted tracheid and stages in the disintegration of the
  secondary wall of other abnormal tracheids. × 330.

Plate XXIII

Agathis resinifera sp. nov.

Fig. 1.—Transverse section of normal wood, showing resin plates in some of the tracheids next to the medullary ray. × 330.

Figs. 2, 3, 4.—Radial longitudinal section, showing the pits on the radial wall of a tracheid at high, medium and low focus respectively. × 1,000.

Fig. 5.—Radial longitudinal section, showing the pits on the radial wall of a tracheid. × 600.

Fig. 6.—Radial longitudinal section of a medullary ray, showing the arrangement of the cross-field pits. × 330.

Fig. 7.—Radial longitudinal section, showing the pits in a single cross-field. × 1,000.

Banksia fossilis sp. nov.

Fig. 8.—Transverse section, showing multiseriate medullary rays with dark festoons of vessels and wood parenchyma between them, and the lighter coloured patches of thick-walled fibres. × 50.

Fig. 9.—Part of the same transverse section. × 100.

Fig. 10.—Tangential longitudinal section of part of a small uniseriate medullary ray. × 330.

Fig. 11.—Radial longitudinal section of part of a large multiseriate medullary ray. × 100.

Fig. 12.—Transverse section of vessels and fibres on the convex side of a festoon. × 330.

Fig. 13.—Radial longitudinal section of a vessel, showing the pitting. × 330.

Fig. 14.—Radial longitudinal section, showing fungal hyphae and the junction of two medullary ray cells. × 330.

Fig. 15.—Tangential longitudinal section, showing fibres, small uniseriate medullary rays and part of two large multiseriate rays; the cells of the multiseriate rays are all distorted. × 100.

Plate XXIV

Casuarina latrobei sp. nov.

Fig. 1.—Transverse section, showing uniseriate and multiseriate medullary rays, scattered vessels with tyloses, and areas of fibres subdivided by tangential bands of wood parenchyma. × 100.

Fig. 2.—Transverse section of a large multiseriate medullary ray, showing parenchyma and fibres. × 100.

Fig. 3.—Transverse section, showing uniseriate medullary rays and thick-walled fibres. × 330.

Fig. 4.—Radial longitudinal section of a large multiseriate medullary ray. × 100.

Fig. 5.—Radial longitudinal section of a uniseriate medullary ray. × 330.

Fig. 6.—Radial longitudinal section, showing the pitting of the vasicentric tracheids. × 330.

Fig. 7.—Tangential longitudinal section, showing fibres, uniseriate medullary rays and a vessel. × 100.

Fig. 8.—Tangential longitudinal section of a large multiseriate medullary ray, showing the network of fibres. × 100.

Fig. 9.—Tangential longitudinal section of a large multiseriate medullary ray, showing the fibres cut longitudinally. × 330.

Fig. 10.—The same, showing fibres cut transversely. × 330.

Fig. 11.—The same. × 200.